Song Analyses of Cicadas of the Genera *Aleeta* Moulds and *Tryella* Moulds (Hemiptera: Cicadidae)

M.S. Moulds
Entomology Department, Australian Museum, 6 College St, Sydney, NSW 2010
maxm@austmus.gov.au

Moulds, M.S. (2005). Song analyses of cicadas of the genera *Aleeta* Moulds and *Tryella* Moulds (Hemiptera: Cicadidae). *Proceedings of the Linnean Society of New South Wales* **126**, 133-142.

The songs of *Aleeta curvicosta, Tryella castanea, T. crassa, T. kauma* and *T. rubra* are analysed. Differences between the songs of the five species are discussed in addition to differences across the distribution of species and within populations. Timbal action of all four *Tryella* species was found to be similar to that of *Aleeta curvicosta*, that is a single muscle contraction produces multiple sound pulses as each rib of the timbal buckles.

A corrigenda to a recent review of the systematics of these genera (Moulds 2003) is provided.

Manuscript received 18 October 2004, accepted for publication 10 January 2005.

KEYWORDS: *Aleeta*, cicada, song, timbal action, *Tryella*.

INTRODUCTION

In a recent review of the genus *Abricta* Stål (Moulds 2003) I showed that the Australian species in that genus are best placed in two new genera, *Abricta curvicosta* (Germar) to *Aleeta* Moulds and the remaining species to *Tryella* Moulds. *Aleeta* and *Tryella* are very distinct from other Australian genera, the nearest being *Chrysocicada* Boulard. Adults characteristically perch head downwards and also call in that position (Fig. 1). They sing both during the heat of the day and at dusk, the dusk call seeming more vigorous. Timbal structure of *Aleeta* and *Tryella* is also very similar, there being many long parallel ribs (9-13 in *Aleeta*, 9-11 in *Tryella*) interspersed by very short ribs (compare figs 20, 22-29 in Moulds 2003).

Below I compare the songs of *Aleeta curvicosta* and four species of *Tryella*. In particular I discuss differences between the five species as well as differences across the distribution of *T. castanea* (Distant) and *T. crassa* Moulds, and differences within a single population of *T. crassa*. I also investigate the timbal contraction mechanisms of the four *Tryella* species and show how these are similar to that of *Aleeta curvicosta*.

Only the song of *Aleeta curvicosta* has been studied previously. Young (1972a) showed that *A. curvicosta* has neurogenic timbal muscles that contract alternately. He also described and illustrated the timbal, which is strongly and evenly ribbed so that during the inward movement each rib buckles separately producing 7-9 separate pulses of sound with each muscle contraction. A similar mechanism has been described for the periodical cicada *Magicicada cassinii* (Fisher) (Young & Josephson 1983b). Young calculated the pulse repetition frequency for the natural song of *A. curvicosta* as 1050/sec and the sound frequency range from 7.5-10.5 kHz. In his second paper concerning sound production in cicadas (Young 1972b), a slow speed oscillogram of the song of *A. curvicosta* was included, which clearly shows the spaced introductory phases characteristic of this species. This paper also included a sonogram of the song not represented in his first paper (Young 1972a).

Young and Josephson (1983a) further investigated timbal muscle contraction and rib buckling in *A. curvicosta* confirming the interpretation of Young (1972a). They calculated the muscle contraction frequency for the timbals as 72 Hz. Some brief additional data concerning the song of *curvicosta* have been provided by Ewart (1995) and Moulds (1990), but no further study of the calling mechanisms has been published.

Figure 1. A male of *Tryella crassa* in full song. The body is raised above the substrate and the wings are held clear to prevent damping. *Tryella* and *Aleeta* species normally sing with the head facing downwards.

MATERIALS AND METHODS

Calling songs were recorded in the field under natural conditions using an Akai X V portable tape recorder at a tape speed of 9.525 cm/sec and an AKG D19C dynamic microphone. Sound analysis data and oscillograms were generated using a Kay DSP Sonagraph Model 5500.

Twenty three recordings were obtained in all, from nine localities, covering a total of four species of *Tryella* across seven localities in addition to a recording from *Aleeta curvicosta* (Table 1).

Acoustic terminology follows that of Greenfield (2002). In particular, a pulse is here defined as ". . a brief packet of sound or vibrational waves that generally corresponds with a single repetitive action". Pulse repetition frequency is defined as the number of pulses produced by the timbals each second and has been calculated from that part of the call containing uninterrupted contractions.

RESULTS

Note: oscillograms and sonograms (Figs 2-27) are at the end of the paper

Song structure by species

Aleeta curvicosta (Germar) recorded at Waverley Creek, Central Queensland (Figs 6, 19), showed song characteristics that agreed closely with data obtained from specimens from New South Wales (Young 1972a, 1972b, and Young & Josephson 1983a, 1983b). Pulse repetition frequency was measured at 1025/s, very close to the 1050/s as measured by Young. Pulses were arranged in syllables as described by Young (1972a), who found that the syllables represented a single buckling of a timbal and each pulse the buckling of a single rib (Fig. 19). In the introductory part of each complete sequence, syllables were grouped into short echemes in which the amplitude rises then suddenly cuts off, with the interval between these echemes gradually decreasing until they merge into the continuous phase; this structure is identical to that described by Young (1972a, 1972b). Young (1972a) also found that within the continuous phase, syllables were grouped into clusters of four, representing four alternating timbal contractions between the right and left timbals. This differs from groupings of three found in an individual from Waverley Creek (Fig. 19). Fig. 19c also shows the coalescence of the syllables produced by the alternate contractions of left and right timbals. Song carrier frequency was 6-12 kHz, also close to the 6.5-11.5 kHz range given by Young. Young (1972b) described the song as having a rasping quality that is clearly more pronounced in this species than in the four *Tryella* species studied.

Tryella castanea (Distant) had a continuous regular call that showed little variation in internal structure. Amplitude modulation was remarkably even overall, but there was strong internal modulation (Figs 3, 7a, 8a, 21a) with the song switching alternately every 0.25 s or so between phrases with syllables compressed and phrases where the syllables were separated by very brief (up to ca. 4 ms) gaps. The syllables are believed to represent single timbal buckles of multiple pulses (see 'Timbal buckling' below). The pulse repetition frequency was measured at approximately 750/s for the dusk call and 1050/s for the day call. The song carrier frequency was

Table 1. Summary of song recordings of *Aleeta curvicosta* and *Tryella* species.

Species	Locality	No. recorded	Date recorded
Aleeta curvicosta (Germar)	QLD: Waverley Ck	1	23-Jan-1992
Tryella castanea (Distant)	NT: Dingo Ck	3	1-Jan-1992
T. crassa Moulds	NT: Adels Grove	3	18-Dec-1991
	NT: Mataranka	5	11-Jan-1992
	QLD: W of Georgetown	3	16-Jan-1992
T. kauma Moulds	QLD: Walkers Ck	1	15-Jan-1992
T. rubra (Goding &	WA: Kununurra	3	1-Jan-1992
Froggatt)	NT: Timber Ck	3	25-Dec-1991
	NT: Top Springs	1	24-Dec-1991

concentrated between 8-13 kHz (Figs 21b, 22b, 23b) with weak side bands extending as low as 2 kHz and as high as 14 kHz (Figs 7b, 8b). To the human ear, the high concentrated frequencies are dominated by the lower side bands which, combined with the rapid but regular pulse repetition frequency, gives the call a vigorous rhythmic buzzing sound.

Tryella crassa Moulds had a continuous, even call that showed little amplitude modulation (Figs 4, 9-14, 20a). Syllables were coalesced into echemes of 14-18 that were interspersed by two, or sometimes three, syllables only slightly separated from each other and the coalesced echemes (Figs 9-14, 25-27). The syllables consisted of a train of pulses inferred to result from a single timbal buckle (see 'Timbal bucking' below) (Fig. 20). The pulse repetition frequency ranged from around 1100/s during the heat of the day to near 850/s during the dusk chorus, but even within single populations noticeable variation was encountered (Figs 12-14). The song carrier frequency was concentrated between 7-12 kHz (Fig. 20b) with an extreme range of approximately 4-15 kHz. This high sound frequency was audible only as a hiss and the ear hears mainly the regular grouped pulse frequencies, which give the song a slight buzzing quality.

Tryella kauma Moulds had a continuous regular song with slight amplitude modulation (Figs 2, 24). Syllables of sound (timbal contractions) were arranged evenly through the call in discrete echemes (approximately 25-70 ms long) with very distinct inter-echeme gaps. The pulse repetition frequency was near 1120/s taken from a recording made during midmorning. The dominant song carrier frequency was concentrated between 8-13 kHz with weak side bands reaching 6 and 14 kHz. These high frequencies and the small size of this species give the song a quiet hiss-like quality.

Tryella rubra Goding & Froggatt had a song distinctly divided into echemes of usually 8-10 syllables (timbal contractions) that were coalesced together, each of similar amplitude (Figs 5, 15-18, 25, 26). The length of these echemes varied within single populations and apparently also between populations (Figs 15-18). Sometimes the interval between echemes contained isolated syllables. The pulse repetition frequency ranged from 1220/s at Kununurra to 1280/s at Top Springs and Kununurra; all specimens were recorded during the heat of the day. The dominant song carrier frequency for all individuals was concentrated between 6-11 kHz (Figs 25b, 26b, 27b) with very weak side bands extending from 1.5 kHz to 12 kHz. These high frequencies and the short repetitive echemes give the song a hiss-like buzzing quality.

Song comparisons

For all five species examined song characteristics clearly differentiate each (Figs 2-6). By far the most distinctive call was that of *Aleeta curvicosta*, primarily because of its unique introductory phrasing of discrete echemes (Fig. 6). In fact, the arrangement of echemes was the main component of song structure to show consistent and easily recognisable differences between all species. While there were some differences in echeme pattern both within and between populations of conspecifics (e.g. in *Tryella crassa,* Figs 9-11 and 12-14), oscillograms clearly showed these differences never approached the degree of difference shown intraspecifically (Figs 2-6).

The characteristic regular pulse pattern of *T. castanea* was identical for two very different

phenotypes of this species from Dingo Creek that otherwise were associated only on the basis of male genitalia and allozymes (Moulds 2003) (Figs 7-8). *Tryella castanea* is one of the most variable of *Tryella* species in both pigmentation and size (see Moulds 2003, Figs 54a-e). The song of *T. kauma* (Fig. 2) is similar to that of *T. castanea* but differs in being a more vigorous call and having a much more even amplitude. The songs of *T. crassa* and *T. rubra* are also similar to each other in that each consists of a regular succession of distinct echemes (Figs 4, 5) and, like *Aleeta curvicosta*, the syllables from individual timbal contractions coalesce together; however the echemes differ structurally (*crassa* with 14-18 syllables per echeme, *rubra* with 8-10) and the echemes are separated by different interval structures.

Pulse repetition frequency was remarkably similar for all five species. Day calls fell within the range 1050-1280/s but were probably dependent to some extent upon temperature. Populations of *T. crassa* had pulse repetitions for day calls ranging from 1220-1280/s. Dusk calls, on the other hand, showed much lower pulse repetition frequencies, as low as 850/s. Dusk calling by *T. castanea* showed a similar low pulse repetition frequency rate of 750/s compared with a day call rate of 1050/s. These low pulse repetition rates for dusk calls are almost certainly a consequence of lower temperatures; very hot day temperatures raise the body temperature of day-calling individuals.

Similarly, song frequency showed little intraspecific variation, the ranges concentrated between 6-13 kHz, but with all species individually showing a broad range of at least 5 kHz, thus making species diagnosis by frequency alone unreliable. However, frequency distribution patterns from sonograms did suggest that further investigation may show features characterising species. For example, *T. castanea* was unique in having weak, but nevertheless distinct, side bands extending to as low as 2 kHz (Fig. 8b).

Timbal buckling

Analyses of the calling songs of these species also provided an opportunity to compare timbal buckling actions. The high pulse repetition frequencies of *T. castanea, T. crassa, T. kauma* and *T. rubra* suggest timbal action equivalent to that detailed for *A. curvicosta* by Young (1972a), where each inward buckle of a timbal produced a train of discrete pulses caused by the individual buckling of ribs.

For all five species studied, oscillogram pulses, when aligned against sonograms comprising only the strongest frequency distributions, showed trains of pulses (syllables) corresponding with clusters of descending frequency. Extrapolating from the work of Young (1972a) for *A. curvicosta,* these are interpreted as individual rib buckles from a single inward buckling of the timbal, the frequency of each rib buckle falling progressively as the timbal collapses. *Aleeta curvicosta* from Waverley Creek showed six such pulses for each timbal buckle (Fig. 19), compared with the 7-9 rib pulses range recorded by Young (1972a). *Tryella crassa* showed 7-8 pulses (Fig. 20), *T. castanea* 6-7 (Figs 21-23), *T. kauma* 9 (Fig. 24) and *T. rubra* 6-7 (Figs 26-27).

While it is unlikely that the numbers I have recorded reflect a full range of the number of pulses resulting from single timbal buckles for each species, evidence suggests that multiple pulsing from a single timbal buckle does occur in all these species. In other words, for each of these species a single inward timbal buckle produces a very rapid pulse train that in turn leads to very high pulse repetition frequencies.

DISCUSSION

The male calling songs of the five species recorded, *Aleeta curvicosta, Tryella castanea, T. crassa, T. kauma* and *T. rubra*, each showed unique characteristics enabling clear separation of each species by song alone. This separation held true for the distinct morphs of *T. castanea*: the songs of the two very different morphs proved identical, confirming the association of these morphs previously derived from male genitalia and allozymes.

The arrangement of the introductory phrases in the song of *Aleeta curvicosta* differed significantly from those of the four *Tryella* species examined, reflecting their generic separation. More subtle differences (e.g. a concentration of intense pulse frequency between 6 and 11 kHz) probably account for the small difference in the perception of the call detectable to the human ear when compared to songs of *Tryella* species. However, there is also an overall similarity in song structure between all five species. All have similar high frequency ranges, similar high pulse repetition frequencies and, at least in part, continuous, regular buzzing sequences to their songs. These characteristics appear to characterise the songs of the Australian *Aleeta* and *Tryella* species. Further, a single timbal buckle in each of the five species appears to give rise to a succession of individual pulses as each rib buckles in succession rather than all ribs buckling in unison as in many other cicadas. It is this multiple pulsing from individual rib buckling that

produces the very high pulse repetition frequencies for *Aleeta* and *Tryella* species.

Corrigenda to Moulds (2003)
p. 245, column 2, line 1: delete 'be'
p. 272, key to species, couplet 3: '16' should read '6'
p. 272, key to species, couplet 4, 3rd line: 'no' should read 'not'

ACKNOWLEDGEMENTS

Dr A. Ewart and Dr D.C. Marshall provided extensive discussion and comments on the manuscript, my wife Barbara and son Timothy gave assistance with field work and Dr Shane McEvey helped with preparing electronic images; to all I am most grateful.

REFERENCES

Ewart, A. (1995). Cicadas. In Ryan, M. (ed.), *Wildlife of Greater Brisbane.* Queensland Museum, Brisbane. Pp. 79-88.

Greenfield, M.D. (2002). *Signalers and receivers: mechanisms and evolution of arthropod communication.* Oxford University Press, Oxford. 414 pages.

Moulds, M.S. (1990). *Australian Cicadas.* New South Wales University Press, Kensington. 217 pages, 24 plates.

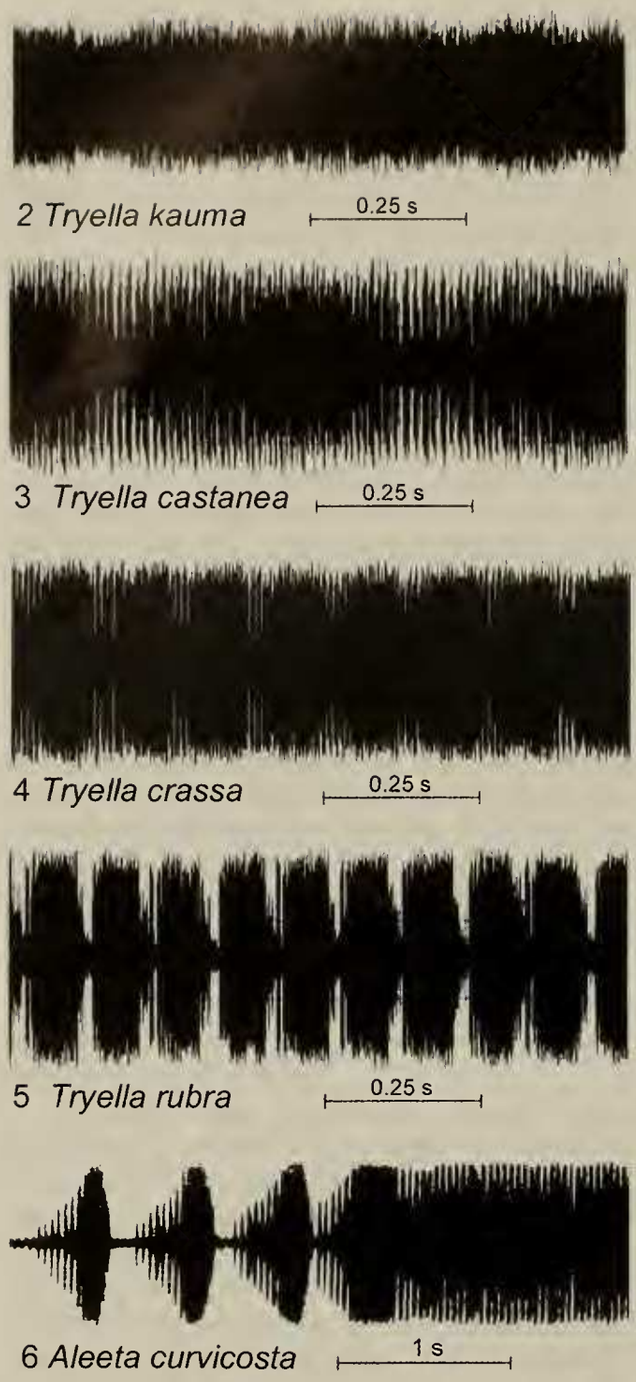
Moulds, M.S. (2003). An appraisal of the cicadas of the genus *Abricta* Stål and allied genera (Hemiptera: Auchenorrhyncha: Cicadidae). *Records of the Australian Museum* **55**, 245-304.

Young, D. (1972a). Neuromuscular mechanism of sound production in Australian cicadas. *Journal of Comparative Physiology* **79**, 343-362.

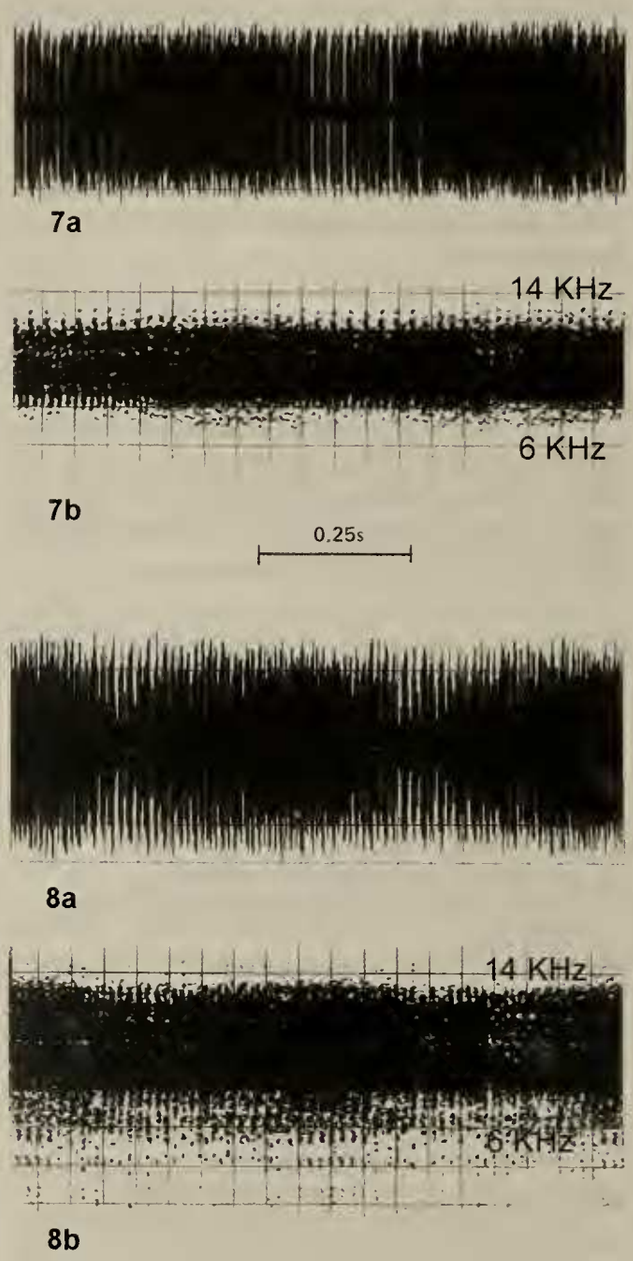
Young, D. (1972b). Analysis of songs of some Australian cicadas (Homoptera: Cicadidae). *Journal of the Australian Entomological Society* **11**: 237-243.

Young, D. and Josephson, R.K. (1983a). Mechanisms of sound-production and muscle contraction kinetics in cicadas. *Journal of Comparative Physiology* **152**, 183-195.

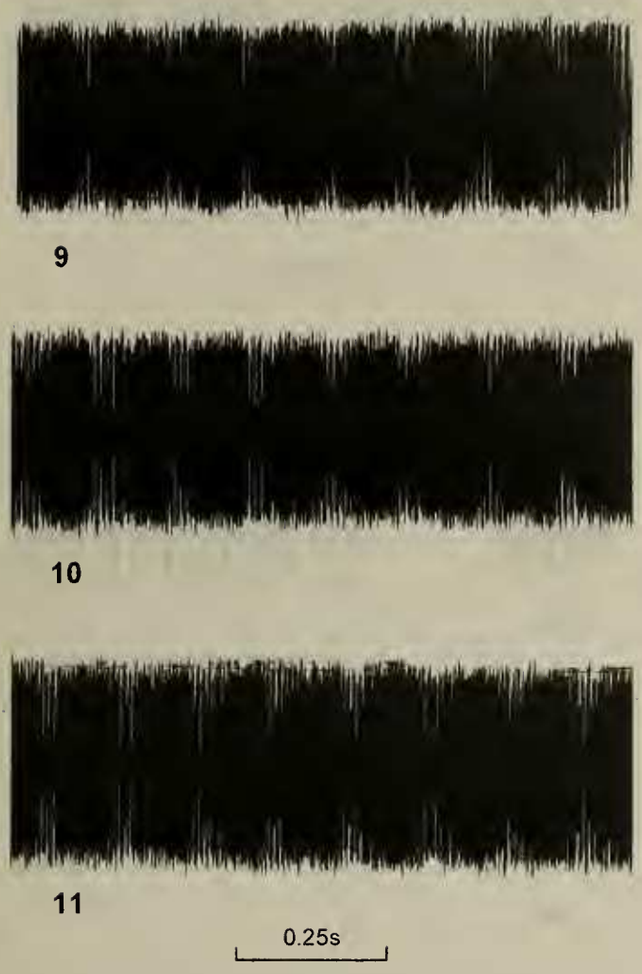
Young, D. and Josephson, R.K. (1983b). Pure-tone songs in cicadas with special reference to the genus *Magicicada. Journal of Comparative Physiology* **152**, 197-207.



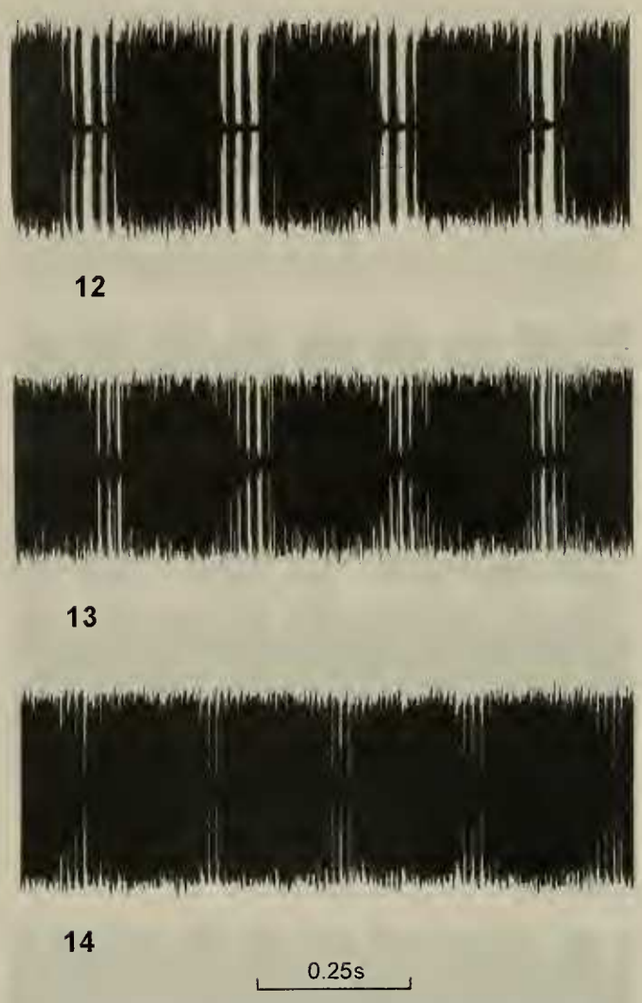
Figs 2-6. Slow oscillograms of the free song (male calling song) of *Aleeta curvicosta* and four *Tryella* species: (2) *T. kauma*, Walkers Creek near Normanton, N. Queensland; (3) *T. castanea*, Dingo Creek, western NT; (4) *T. crassa*, Mataranka, NT; (5) *T. rubra*, Top Springs, NT; (6) *A. curvicosta*, after Young and Josephson, 1983a. Note that figure 6 is at a different time scale.



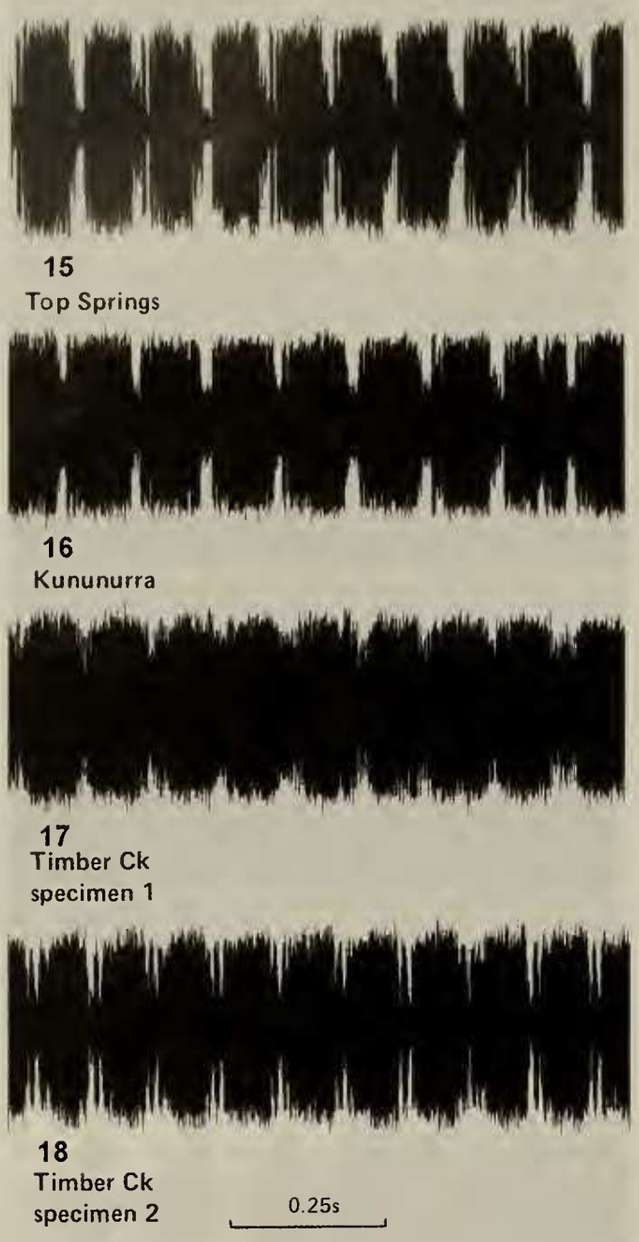
Figs 7-8. *Tryella castanea*; (a) synchronised oscillograms and (b) sonograms for two males from Dingo Creek, NT: (7) dark individual; (8) pale individual. (a) Waveform and (b) spectrographic analyses.



Figs 9-11. *Tryella crassa*; slow speed oscillograms at identical time scale of day call for 3 individuals recorded during a 35-minute interval from 40km W of Georgetown, Qld.



Figs 12-14. *Tryella crassa*; slow speed oscillograms recorded during a 10-minute interval, at identical time scale, of dusk call for 3 individuals from Mataranka, NT: (12) echemes widely separated by intermediate syllables (i.e. single timbal contractions); (13) echemes with moderate separation; (14) echemes with minimum separation.



Figs 15-18. *Tryella rubra*; oscillograms of day calls at identical time scales for 4 individuals: (15) Top Springs, NT; (16) Kununurra, WA; (17-18) Timber Creek, NT

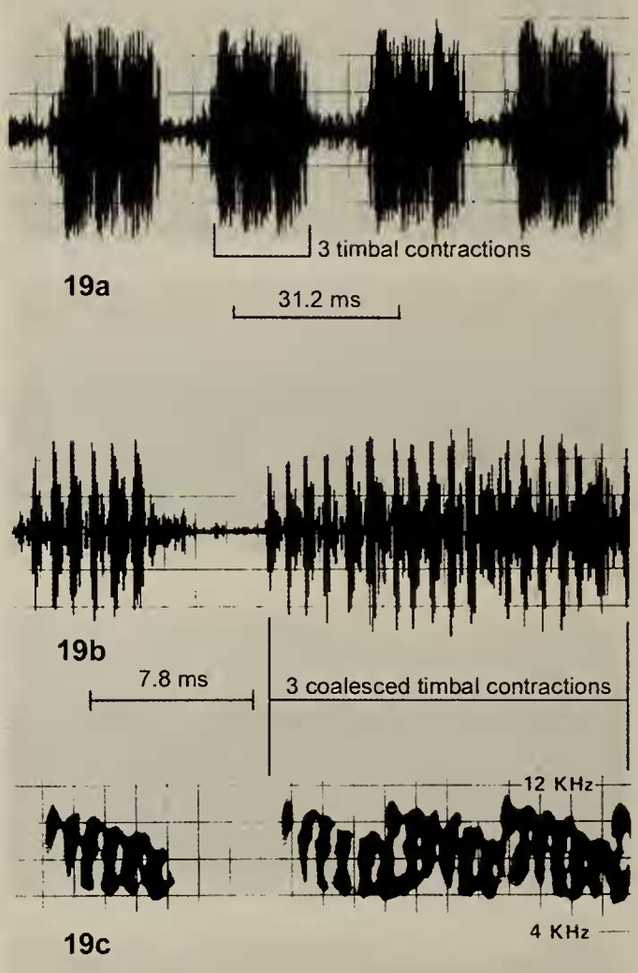


Fig. 19. *Aleeta curvicosta*; slow speed oscillogram of the (a) free song, (b) synchronised high speed oscillograms, and (c) sonogram of day call from an individual from Waverley Creek, Central Queensland. (b) and (c) show a sequence of three timbal contractions showing the coalescence of the syllables from these contractions.

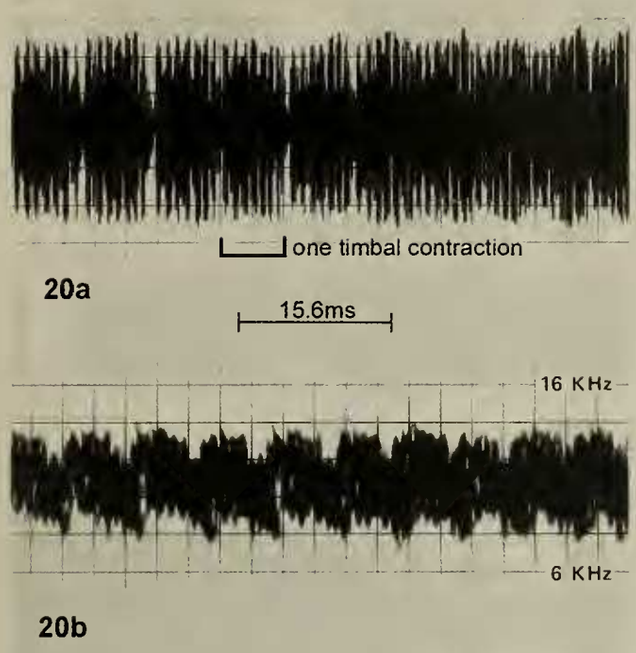
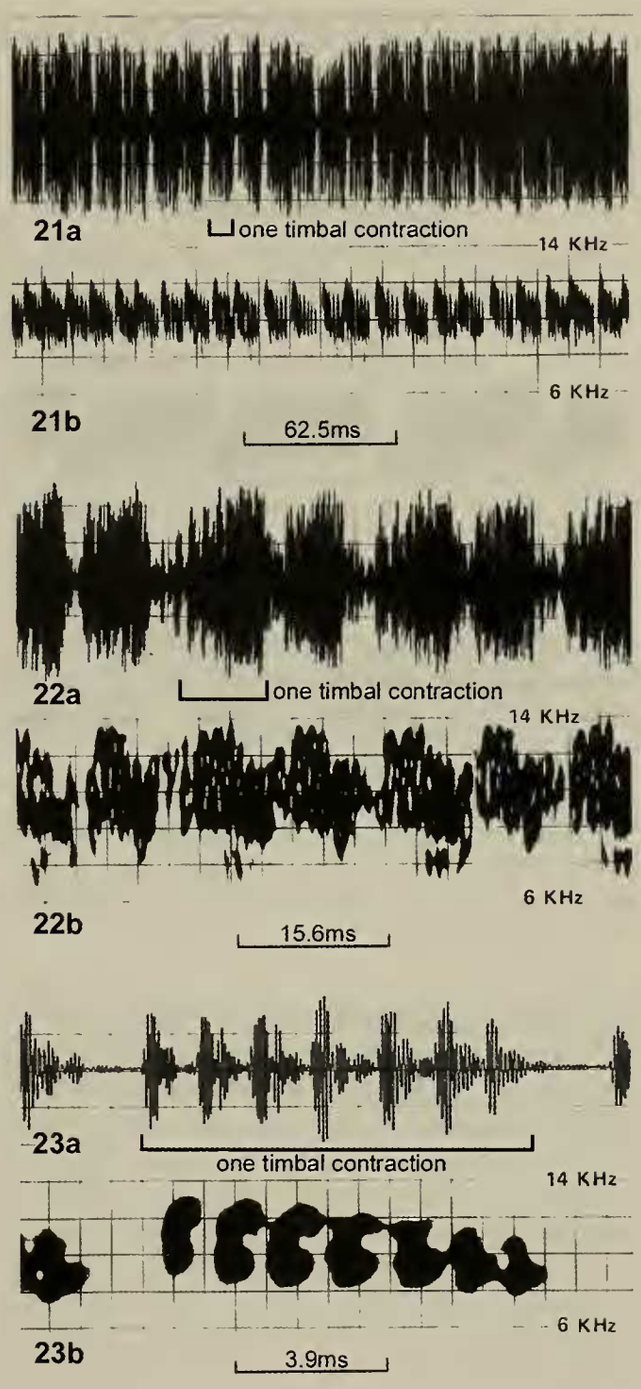


Fig. 20. *Tryella crassa*; (a) synchronised oscillogram and (b) sonogram of dusk call for an individual from Adels Grove, Lawn Hill Stn, Queensland.



Figs 21-23. *Tryella castanea*; (a) synchronised oscillograms and (b) sonograms of day call for a single individual from Dingo Creek, NT: (21) a train of pulses; (22) portion of the same train of pulses at greatly increased time scale showing individual timbal buckles within a series of timbal contractions; (23) a single timbal contraction showing sound pulses generated from the separate buckling of seven ribs.

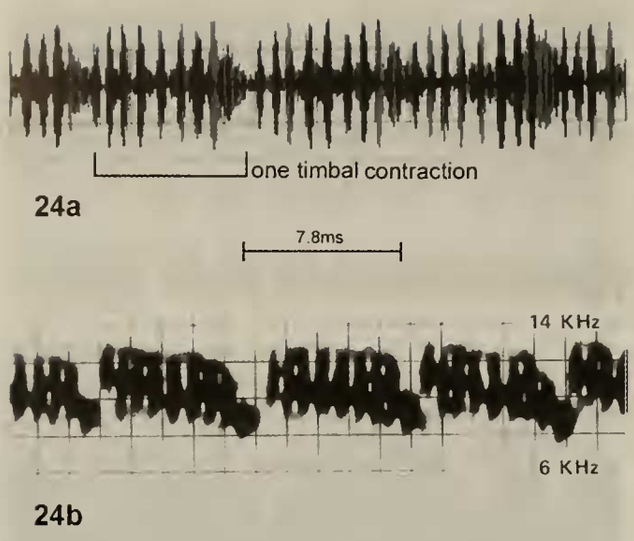
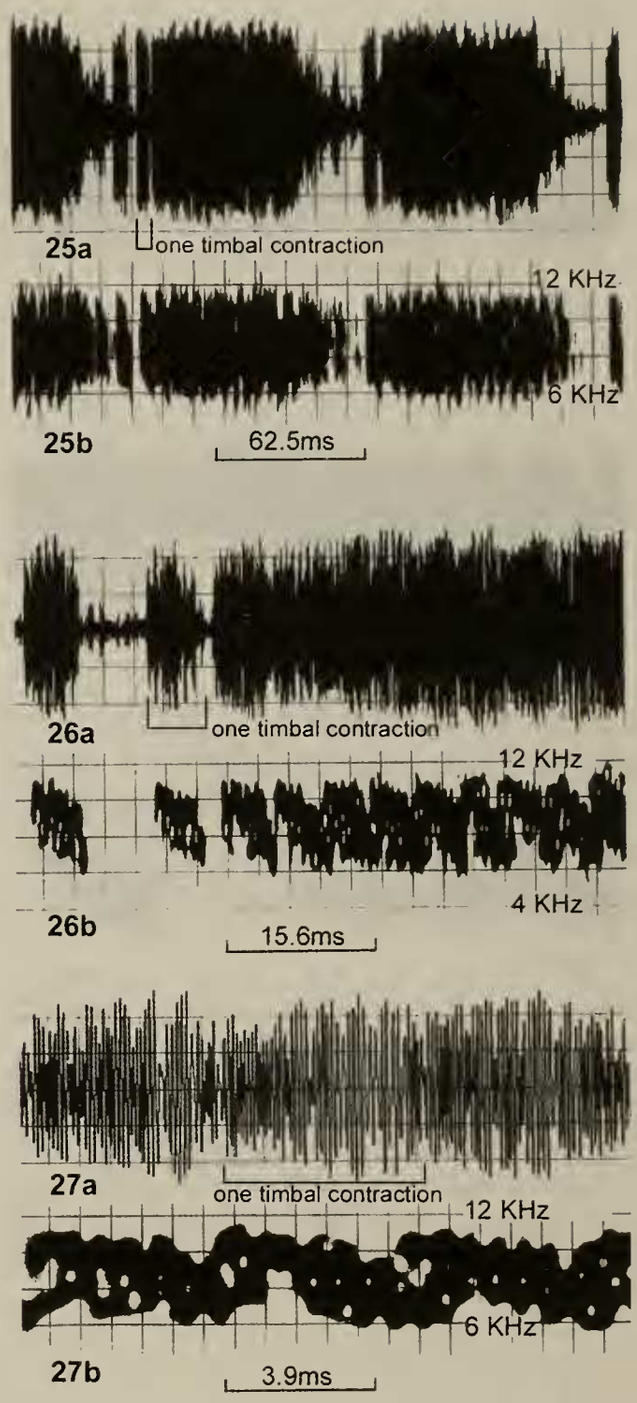


Fig. 24. *Tryella kauma*; (a) synchronised oscillogram and (b) sonogram of day call for an individual from Walkers Creek, Queensland.



Figs 25-27. *Tryella rubra*; (a) synchronised oscillograms and (b) sonograms of a day call for a single individual from Top Springs, Queensland: (25) a train of pulses; (26) portion of the same train of pulses at greatly increased time scale, the sonogram showing positions of individual timbal buckles; (27) a sequence of three timbal contractions showing the coalescence of the syllables from these contractions.